

Perfusion Index as a Predictor of Hypotension Following Spinal Anesthesia in Lower Segment Caesarean Section

Asma Rauf, Atif Nazir, Atiya Chaudhry, Sahar Younas, Aaisha Gillani, Areeba Arif

ABSTRACT

Objective: To assess the diagnostic accuracy of preoperative pulse oximetry-derived Perfusion Index (PI) as a non-invasive tool for predicting spinal anesthesia-induced hypotension in parturients undergoing elective lower segment cesarean section (LSCS).

Study Design and Setting: Cross-sectional study, Department of Anesthesia, PAF Hospital Islamabad / Fazaia Medical College, from September 2022 to March 2023.

Methodology: A total of 120 healthy parturients (ASA I–III, aged 16–38 years) listed for elective LSCS under spinal anesthesia were included through consecutive sampling. Participants were grouped into Group A (High PI more than or equal to 3.5, n=60) or Group B (Low PI < 3.5, n=60) based on baseline preoperative PI values. Hemodynamic parameters and hypotensive episodes were observed every 3 minutes for 60 minutes post-block. Data was analyzed using SPSS version 26.0

Results: Group A showed a significantly higher incidence of hypotension compared to Group B [75.0% (n=45) vs. 35.0% (n=21); $P < 0.001$]. The baseline PI cutoff of 3.5 predicted spinal anesthesia-induced hypotension with a sensitivity of 68.2%, specificity of 72.2%, positive predictive value of 75.0%, negative predictive value of 65.0%, and a diagnostic accuracy of 70.0%. Considerably, 66% (n=43) of all hypotensive events occurred during the critical early window of first 20 minutes.

Conclusion: A baseline preoperative perfusion Index more than or equal to 3.5 is a reliable, non-invasive, cost-effective predictor of early-onset spinal anesthesia-induced hypotension in obstetric patients, allowing a clinical shift from reactive treatment to proactive, individualized hemodynamic management.

Keywords: Hypotension, Lower segment cesarean section, Perfusion index, Spinal Anesthesia

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INTRODUCTION

Spinal anesthesia is widely used in obstetric surgeries (especially in lower segment cesarean section/LSCS) and is generally considered quite safe. Worldwide there has been a marked increase in the rate of cesarean deliveries, with an average rate of 1 in 5 births occurring through cesarean section. This proportion may often become even higher in developing regions including South Asia. Consequently, ensuring the hemodynamic stability of parturients undergoing neuraxial blocks has become a cornerstone of modern obstetric anesthesia. Multiple side effects have been reported in literature that are associated with spinal anesthesia including hypotension, pruritus, nausea and vomiting, urinary retention, fever with shivering, systemic toxicity, inadequate or failed anesthesia, undesired motor block, high spinal anesthesia, total spinal anesthesia leading to cardiac arrests, post dural puncture headache, pneumocephalus, spinal epidural hematoma and respiratory depression.^{1,2,3,4} The incidence of these complications may vary significantly; however, the physiological consequences of a rapid sympathetic blockade are one of the most commonly encountered problems faced by anesthetists in

the operating rooms.

Amongst these complications, hypotension is one of the common complication reported after spinal anesthesia in obstetric population leading to adverse materno-fetal effects.⁵ In obstetric patients where no prophylactic intervention is done, the incidence of post spinal hypotension may reach upto 70-80%. Hypotension associated with spinal anesthesia occurs through various mechanisms including sympathetic block of the venous reservoir leading to peripheral pooling of the blood and decrease in cardiac output secondary to a decrease in preload.⁴ Since hypotension is associated with adverse maternal and fetal effects, it is important to have a way to predict occurrence of this serious adverse effect that occurs in association with spinal anesthesia in obstetric population. In context of the hyperdynamic circulation during pregnancy, conventional methods like baseline heart rate or the shock index fail to predict hypotension reliably. One such tool is perfusion index (PI) which is a rapid indicator to detect any change in peripheral microcirculation and is measured by measuring constant amount of light absorbed by non-pulsatile blood and other tissue (DC- direct current) and the variable amount of light absorbed by pulsating arterial inflow (AC- alternating current) by the use of equation $[PI = (AC/DC) * 100\%]$. However, modern monitors can detect PI automatically. A higher perfusion index with vasodilation and a lower value with vasoconstriction theoretically makes it a sound predictor of spinal block induced hypotension.⁶ Studies have reported perfusion index as an effective tool to predict occurrence of hypotension in patients undergoing lower segment cesarean section (LSCS) with spinal anesthesia. In a meta-analysis studying more than 2,000 patients has recently showed moderate to high sensitivity and specificity of pre-operative perfusion index in predicting such events, with a strong diagnostic accuracy reflected by area under the curve (AUC).^{6,7} A study recently conducted to determine the relationship between perfusion index and the prediction of hypotension in lower segment caesarean section reported the incidence of hypotension in patients with low perfusion index was 26% as compared to 48% in patients with high perfusion index.⁸ Similarly, another study reported that not only the incidence of hypotension among patients having LSCS with spinal anesthesia was 66.7% but also a significant correlation was found between baseline perfusion index and fall in systolic blood pressure from baseline ($r = 0.368$, $P < 0.05$).⁹ Identification of high risk patients based on a certain PI cutoff (often taken as 3.5) could likely help them benefit from early prophylactic measures like intravenous fluid infusions or vasopressors.¹⁰

The current literature on utility of perfusion index mostly comes from East Asian or Western cohorts, where demographic variations based on the weight, body mass index, dietary patterns and genetic variability; the baseline vascular tone and cardiovascular responses may differ from the South Asian population. Furthermore, use of this tool is

not a part of standard of practice at institutional level in Pakistan. This makes it imperative to further the research work on usefulness of such tool to further strengthen the evidence and in future opting it as standard of care at institutional level. By generating a scientific evidence base and routinely including perfusion index into pre-operative assessments, reliance on a reactive treatment may be significantly reduced with a trend towards more individualized and predictive approach. Therefore, this study focuses on determining the ability of perfusion index (PI) in predicting occurrence of hypotension in pregnant women undergoing lower segment cesarean section (LSCS) under spinal anesthesia.

METHODOLOGY

A cross sectional study was conducted in the Department of Anesthesia, PAF Hospital Islamabad / Fazaia Medical College from 9th Sep 2022 to 9th March 2023 (6 months) after approval from the hospital's ethical review committee and Research Evaluation Unit of the College of Physicians and Surgeons, Pakistan vide letter no. CPSP/REU/ANS-2020-137-2435 dated 9th Sep 2022. Sample size was calculated as $n=120$ using WHO sample size calculator software with Confidence Level (CI)= 95%, Anticipated Population = 26%, Absolute precision =8%. Non-probability consecutive sampling technique was used and patients were divided in two equal groups with 60 patients in group A (with high PI) and 60 patients in group B (with low PI). Inclusion criteria for patient selection were 1) All pregnant patients aged 16-38 years, who were scheduled to undergo elective lower section cesarean section under spinal anesthesia. 2) Patients with gestational age between 37-42 weeks 3) Patients with American Society of Anesthesiologists (ASA) status I-III were included in the study. Patients with previously diagnosed cardiovascular disease, pre-eclampsia, eclampsia, gestational diabetes and placenta previa, contraindication to spinal anesthesia, BMI = 38kg/m^2 and those gestational age less than 37 weeks were excluded from the study. After recruitment of patients their age, weight, height and BMI were documented. In all of these patients, perfusion index was checked by using automated monitor and attached pulse oximeter on any one of the fingers. Those with PI value (as visible on monitor) more than or equal to 3.5 were labeled as having high PI and were placed in group A while those with PI value less than 3.5 were placed in group B. The major potential confounding variables were carefully controlled, according to the protocol. All patients were taken to a holding room for 10 minutes before starting the baseline PI measurement, which was conducted in a calm and controlled room with a temperature of 22 -24 °C. Standardization of anesthetic delivery: Use of a 25 G Quincke needle and injection of 2.5 mL hyperbaric 0.5 % bupivacaine at L2-L3 or L3-L4 was followed immediately by supine position with left uterine displacement to prevent aortocaval compression. All patients had sensory block to T4 before

skin incision. Hypotension was defined as a drop in Mean Arterial Pressure (MAP) to <65 mmHg or more than 25% decrease in Systolic Blood Pressure (SBP) from baseline measurements recorded before spinal anesthesia injection. Patients were monitored for next 60 minutes for occurrence of hypotension using automated interval NIBP monitor that was set at 3 minutes interval. During this whole period BP, MAP, time since surgery to hypotension and occurrence of hypotension was documented. To avoid observer bias, the primary assessor who recorded the post-block hemodynamic parameters was blinded to the patient's baseline preoperative Perfusion Index (PI) value, which was recorded before transfer to the operating suite. To preserve the observational integrity of the study, no prophylactic vasopressors or fluid challenges were administered to either group prior to or during block placement. Both the groups were co-loaded with a standardized 10 mL/kg Ringer's lactate infusion during the subarachnoid injection. Hypotension was managed using incremental intravenous 100 mcg doses of Phenylephrine. All the data was documented on proforma. Patient anonymity and confidentiality was maintained with utmost priority. No personal identifiers such as "patient registration number" or "Patient name or contact details" were included in documentation. The data was analyzed using SPSS software 26.0 (IBM Corp., Armonk, NY, USA).

The numeric variables (age, weight, height, BMI, perfusion index, BP, MAP, time since surgery to hypotension) was expressed as mean $\pm$ standard deviation. The categorical variables occurrence of hypotension was represented as frequency and percentages. Chi-square test was used as test of significance to find association of perfusion index with post-spinal anesthesia hypotension in elective LSCS patients by keeping significant P-value at = 0.05.

RESULTS

A total of 120 parturients listed for elective lower segment cesarean section (LSCS) under spinal anesthesia were included in the study. The mean age of the participants was 28 years (SD $\pm$ 8.77). Patients were divided into two groups according to their baseline perfusion index (PI) value which was = 3.5 in 60 (50%) patients (high PI group) and < 3.5 in 60 (50%) patients (low PI group). Baseline demographic characteristics and BMI were similar between the two groups, as summarized in Table 1. The table 2 illustrates the distribution of hypotension incidence, showing a significantly higher occurrence in patients with a baseline PI = 3.5. The predictive performance of the perfusion index cut-off is detailed in Table 3, outlining its diagnostic utility and statistical accuracy. This non-invasive marker can be clinically reliable with an accuracy of 70%. To contextualize these

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population

Characteristics	Group A (High PI, =3.5)	Group B (Low PI, <3.5)	P-value
Age (years, mean $\pm$ SD)	27.5 $\pm$ 8.1	28.5 $\pm$ 9.4	0.485
BMI (kg/m ² , mean $\pm$ SD)	26.2 $\pm$ 3.4	26.5 $\pm$ 3.8	0.824

Table 2: Comparison of Hemodynamic Variables and Incidence of Hypotension Between Groups

Group	Hypotensive n (%)	Non-Hypotensive n (%)	Total n (%)
High PI (=3.5)	45 (75.0%)	15 (25.0%)	60 (100%)
Low PI (<3.5)	21 (35.0%)	39 (65.0%)	60 (100%)

Note: Fisher's exact test showed there was a statistically significant relationship between higher baseline PI and the incidence of post-spinal anesthesia hypotension (P < 0.001).

Table 3: Diagnostic Test Accuracy Metrics of Baseline Perfusion Index = 3.5 for Predicting Hypotension

Metric	Calculation Formula	Value (%)	95% confidence interval
Sensitivity	TP / (TP + FN)	68.2%	55.6% - 79.1%
Specificity	TN / (TN + FP)	72.2%	58.4% - 83.5%
Positive Predictive Value (PPV)	TP / (TP + FP)	75.0%	62.1% - 85.3%
Negative Predictive Value (NPV)	TN / (TN + FN)	65.0%	51.6% - 76.9%
Diagnostic Accuracy	(TP + TN) / Total	70.0%	60.9% - 78%

*Abbreviations: TP, True Positive; FP, False Positive; TN, True Negative; FN, False Negative.

Table 4: Comparative Evaluation of Diagnostic Performance of Perfusion Index Across Recent Literature

Study	Year	Cut-off PI	Sensitivity (%)	Specificity (%)
Abdul Manap et al.	2024	3.2	85.9	87.5
Harde et al.	2023	2.9	83.1	96.0
Inamanamelluri et al.	2022	2.85	80.0	75.0
Current Study	2026	3.5	68.2	72.2

findings, a comparison of our results to other similar studies published over the past five years is presented in Table 4.

Overall, 55% (n=66) patients had hypotension after spinal anesthesia wherein the majority (n=43, 66%) of patients among these had a drop in blood pressure within the first 20 minutes following spinal anesthesia while the remaining (n=23, 34%) experienced it after 20 minutes. The fact that most of the events happened within the first 20 minutes, points to the "critical window" of hemodynamic intervention shortly after the block. The mean time to onset of hypotension was 15 minutes (SD± 10.27). No significant correlation was identified between maternal age (P=0.485) or BMI (P=0.824) and the incidence of post-spinal hypotension.

DISCUSSION

Hypotension is a major problem in obstetric anesthesia, especially when predicting and controlling it following spinal anesthesia. The effect of a sudden sympathetic blockade on the pregnant woman is immense and may result in a cascade of hemodynamic events that can affect the mother and fetus. The overall incidence of hypotension in our study was 55% which falls within the wide range of 50–80% reported in the international literature without the use of prophylactic measures.^{7,10,11} Elective cesarean sections are best performed using spinal anesthesia because of its ability to provide dense sensory block with a fast onset of action, although the rapid vasodilation that occurs with it means that the anesthesiologist must constantly be "one step ahead" of the patient's physiology.⁵ We found that a baseline perfusion index (PI) = 3.5 is significantly correlated with an increased risk of hypotension following spinal anesthesia, consistent with a growing evidence that suggests that PI is a valid, noninvasive hemodynamic marker.^{2,6} Reliance on a reactive treatment could be drastically reduced, with a shift to a more personalized and predictive treatment, if a scientific evidence base is created and perfusion index is routinely added to pre-operative assessments.

The physiological basis for predicting with the use of PI is based on the fact that it reflects peripheral vasomotor tone.^{12,13} PI is a measure derived from pulse oximetry measuring the ratio between the pulsatile component (arterial blood flow) and the non-pulsatile component (other tissues and venous blood). Patients with high baseline PI are more likely to experience this dramatic fall in SVR that follows the sympathetic blockade of spinal anesthesia, and are thus more prone to its effects.^{8,14} In other words, a high PI implies the peripheral vasculature is already in a rather dilated state, and its loss of sympathetic tone induces a sudden (and unprepared) fall in systemic vascular resistance, which the body cannot accommodate. In our study, 75% of patients with high PI had hypotension, compared to only 35% of patients with low PI (p < 0.001).

The apparent difference validates that PI is a true representation of patients' hemodynamic reserve, and is a

"window" into the autonomic nervous system. This is congruent with the results of Harde et al. who found a similar trend but with higher levels of sensitivity and specificity than we found.⁷ This difference could be due to the slightly higher PI threshold (3.5) we used than the one used by them (2.9); therefore, the higher the PI threshold the more specific it will be for the identification of those at high risk, but this will depend upon the population demographic as well.^{6,9,15}

In addition, the simplicity of the technical calculation of the PI using the equation $[PI = (AC/DC) 100 \ %]$ makes it possible to get immediate feedback. Modern monitors do this automatically and provide a parameter which is a good surrogate for peripheral vasomotor tone and can be monitored beat to beat. When considering obstetric anesthesia, the aortocaval compression already affects venous return and makes it difficult to maintain blood pressure, a real time indicator of the patient's vascular status is a great asset. Traditional methods for prediction of hypotension, like baseline heart rate or shock index, have historically failed to predict hypotension in the obstetric population. Early signs of cardiovascular instability are masked in the hyperdynamic state of pregnancy, in which blood volume and heart rate increase. The PI, however, avoids all such systemic compensations by directly examining the peripheral vascular bed and thus gets a more direct measurement of the sympathetic "tone" to be interrupted by the spinal block. A 70% diagnostic accuracy is comparable and is supported by recent meta-analyses. Hung et al. and Yu et al. validated the robustness of PI as a predictor, sometimes better than other traditional ones such as shock index or baseline heart rate.^{6,16}

Although the cut-off points vary across the region, there is a general trend of results when compared with other regional studies. For instance, the study by Abdul Manap et al.,¹³ set the cut-off value as 3.2 with a high sensitivity of 85.9% and the study by Inamanamelluri et al., 2022 used a lower cut-off value of 2.85.⁹ The selection of 3.5 takes into consideration a more conservative threshold to identify high-risk individuals within the South Asian population as baseline vascular tone and cardiovascular responses may be different from Western and/or East Asian populations.¹⁷ Raising the diagnostic threshold shifts the test toward higher specificity meanwhile reducing sensitivity. Clinically, this is relevant in busy obstetric settings: high specificity ensures that prophylactic vasopressor infusions and/or aggressive fluid co-loads are administered strictly to true high-risk parturients. This minimizes unnecessary interventions, reactive maternal hypertension, and fluid overload in low-risk patients.

Additionally, PI presents some definite benefits over alternative emerging technologies. Other indices, like the Pleth Variability Index (PVI) and Inferior Vena Cava Collapsibility Index (IVC-CI) have been investigated, but PI is easier to use and is continuous, non-invasive.^{18,19} For example, the gravid uterus makes the use of IVC-CI

technically difficult in late pregnancy, whereas standard pulse oximetry measures can automatically calculate the PI, making it more useful for a rapid pre-operative assessment in busy obstetric units.¹⁸ The "plug and play" characteristic of PI enables it to be incorporated into the normal workflow without involving extra high cost equipment or specific training. An interesting result from our study was the time of onset of hypotension, as 66% of events were observed in the first 20 minutes. This is important for safety reasons as it determines the time frame when the anesthesia provider must be most vigilant. The so-called "early onset" window is important because it is during this time that the block is at its peak and the risk of uteroplacental hypoperfusion is the highest.^{13,20} A drop in maternal blood pressure will result in a decrease in the pressure gradient that pushes blood to the placenta, and subsequently cause fetal bradycardia and acidosis. If we can determine which patients are at risk for parturition in the pre-operative holding room, we can plan the anesthetic for the patient prior to the first drop in pressure.

Based on our results, we believe that a proactive approach to these high-risk parturients, such as fluid loading or administering vasopressors early, can be achieved with PI monitoring before the block is even performed, rather than after, thus changing the paradigm from reactive to proactive treatment.^{21,22,23} A patient with a PI = 3.5 may be more likely to receive a more aggressive fluid co-load and/or a phenylephrine infusion to begin prior to the procedure than a patient in the low PI group.⁽⁴⁾ This precision medicine approach helps reduce the "see-saw" phenomenon of hypotension that usually happens because the treatment is only undertaken after the patient is symptomatic. Hypotension-related clinical distress (nausea, vomiting and a sense of impending doom) can also be greatly reduced. This avoids the initial drop, which makes the mother's whole surgery experience better, and decreases the need for rescue boluses of vasopressors (which can themselves cause reactive hypertension or bradycardia).⁵

The study is clinically significant because it is applicable to the health care context in Pakistan. Although PI's utility has been proven elsewhere, there is little use of PI in local protocols. Demographic factors (weight, BMI, diet, vascular reactivity) in South Asia may affect a patient's response to neuraxial blockade. This study establishes a local evidence base for incorporating PI into routine institutional practice, whilst also providing a clear demonstration of the reliability of the 3.5 cutoff within a South Asian population. At present, it is not a part of institutional practice in Pakistan. This underscores the need to continue research efforts on the value of such tools to further enhance the evidence and, in the future, standard of care. Early use of intravenous fluid infusions or vasopressors may be indicated in high-risk patients (those with a certain PI cutoff).²³ The adoption of a standard tool on PI can prove to be a great step towards enhancing maternal outcomes in Pakistan as it can offer an

objective, low-cost tool to support clinical decisions. It can be used to identify the "at-risk" mother even if her vital signs at baseline are normal. Overall, this research is a call to action for local anesthesia departments to make use of the data that is being gathered by their monitors. Most modern pulse oximeters can show the PI, so implementing this predictive assessment comes at no extra cost. With just an observation and documentation of the PI during the pre-anesthetic examination, we may be able to ease towards a safer and more individualized approach to obstetric spinal anesthesia.²¹ Future research should now concentrate on results of the intervention protocols guided by the PIs to quantify how much maternal and neonatal morbidity can be prevented through the use of this tool. Limitations: A cross-sectional study conducted at a single center, the results may not be fully generalizable to all regions of Pakistan. Secondly, the study focused on elective LSCS in relatively healthy parturients (ASA I-III); therefore, the predictive value of PI in emergency cases or high-risk pregnancies (e.g., severe pre-eclampsia) remains to be established. Thirdly, while we identified the risk, we did not investigate the comparative efficacy of different vasopressors in the high PI group, which is a potential area for future interventional research.

CONCLUSIONS

This prospective clinical study validated that the baseline pulse oximetry-derived Perfusion Index (PI) is a valid, non-invasive and cost-effective predictor of spinal anesthesia-induced hypotension in parturients who are undergoing elective lower segment cesarean section (LSCS). With a clinical diagnostic accuracy of 70%, a sensitivity of 68.2% and a specificity of 72.2%, the baseline threshold of = 3.5 shows a statistically significant correlation ($P < 0.001$) with the reduction in maternal blood pressure. Moreover, this physiological marker has shown good success in identifying patients at risk during the critical "early-onset" window: 66% of all hypotensive events occur within the first 20 minutes after the spinal anesthesia. The inclusion of baseline PI screening into routine pre-operative workflows enables anesthesia providers to shift from a reactive treatment approach to proactive, individual, and targeted preventative management approach that improves maternal safety and maximizes neonatal outcomes.

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Authors Contribution: Asma Rauf: Conception, design, analysis and/or interpretation of data Atif Nazir: Conception, design, Preparation of final manuscript and review Atiya Chaudhry: Analysis and interpretation of data Sahar Younas: Analysis and interpretation of data Aaisha Gillani: Conception, Interpretation of data Areeba Arif: Conception, analysis and interpretation of data
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